*Jan 1999*
*Submission.*

## TABLE OF CONTENTS

## 3.0   IDENTIFICATION AND SIGNIFICANCE OF THE PROBLEM OR OPPORTUNITY

This effort proposes a true innovation in the combined areas of missile guidance and ordnance fuzing that will lead to the development of a single imaging detector array with the capability of performing both functions simultaneously. A coordinated effort between Nova Research, Inc. and Optics 1, Inc. is proposed that will result in the development of a "Guidance Integrated Fuzing" (GIF) system requiring no gimbals, and which has essentially a full $4\pi$ steradian field of view (see Optics 1 proposal titled "Missile Guidance and Fuzing Using a Single Optical System and Aerodynamic Domes" by Mike Couture of Optics 1).

Elimination of the sensor gimbal and combining the guidance and fuzing functions of heretofore two independent detection and processing systems will reduce complexity, weight and cost, and will greatly improve the overall reliability of the system. Revolutionary optical and infrared detection design techniques must be used to design a "Focal Geometric Array" (FGA) that achieves the combined GIF functions by virtue of its unique design.

The FGA will not be flat, as are conventional FPA devices. It will have some of the characteristics of a foveated sensor in which the size and detectivity of individual detector channels are designed to conform to the angular requirements of the system optics. The purpose of this effort will be to define requirements and produce initial designs for the FGA.

### 3.1    Proposed Focal Geometric Array (FGA) System

A single detector assembly is proposed to satisfy both the guidance and ordnance fuzing functions of the interceptor. As the technology is advanced, one may consider the development of a "curved" focal plane array which optimally conforms to the focal surface of wide-angle system optics. Silicon-based technology, though, currently requires readout integrated circuits (ROICs) and associated preprocessing integrated circuitry to be fabricated on flat wafers. As an intermediate step leading to the eventual development of a conformal FGA, we propose the development of a cryogenic substrate which provides sufficient mounting surfaces for flat FPA devices such that the combined detector structure approximates the geometrical characteristics of an optimal FGA. Figure 3.1-1 shows a conceptual picture of the preliminary FGA in a micro-dewar system. The FGA assumes a focal surface shape which will actually be determined through Nova's association with Optics 1.

Nova's micro-dewar system is currently being designed under a concurrent program (contract # F08630-98-C-0078, "Autonomous Detection of Missile Targets Using Neuromorphic Multi-Chip Module Techniques") and is intended to support imaging focal plane arrays that produce data that must be processed in real-time. The dewar itself becomes an important part of the overall system, in that it incorporates electronics used to operate the cryogenic detector as well as perform important preprocessing operations on the data.

The FGA assembly uses the dewar electronics to provide clock and bias signals to the internal FPA devices, and will apply real-time image processing operations to the resulting data. For example, the FPA located directly on the upper surface of the FGA assembly will probably be used for collection of imaging data used for guidance control of the interceptor body. Depending upon the control requirements and the optical design used for this task, the required FPA may have foveal characteristics; i.e., the central portion of the FPA may have higher spatial frequency than that of its outer pixels. The individual FPA devices used on the FGA can be tailored to suit the specific system needs based upon their location in the FGA assembly.

Nova's micro-dewar also makes use of a variety of modular daughterboards located outside the vacuum enclosure to permit sophisticated real-time image processing operations to be applied to the image data. Section 3.2 introduces powerful operations which may be applied to the data in the analog domain on one or more of these daughterboards. Other digital operations may also be applied to the data on their respective circuit cards. The modular approach to this design helps keep the system designer's options open as mission requirements are shaped through the course of the program.
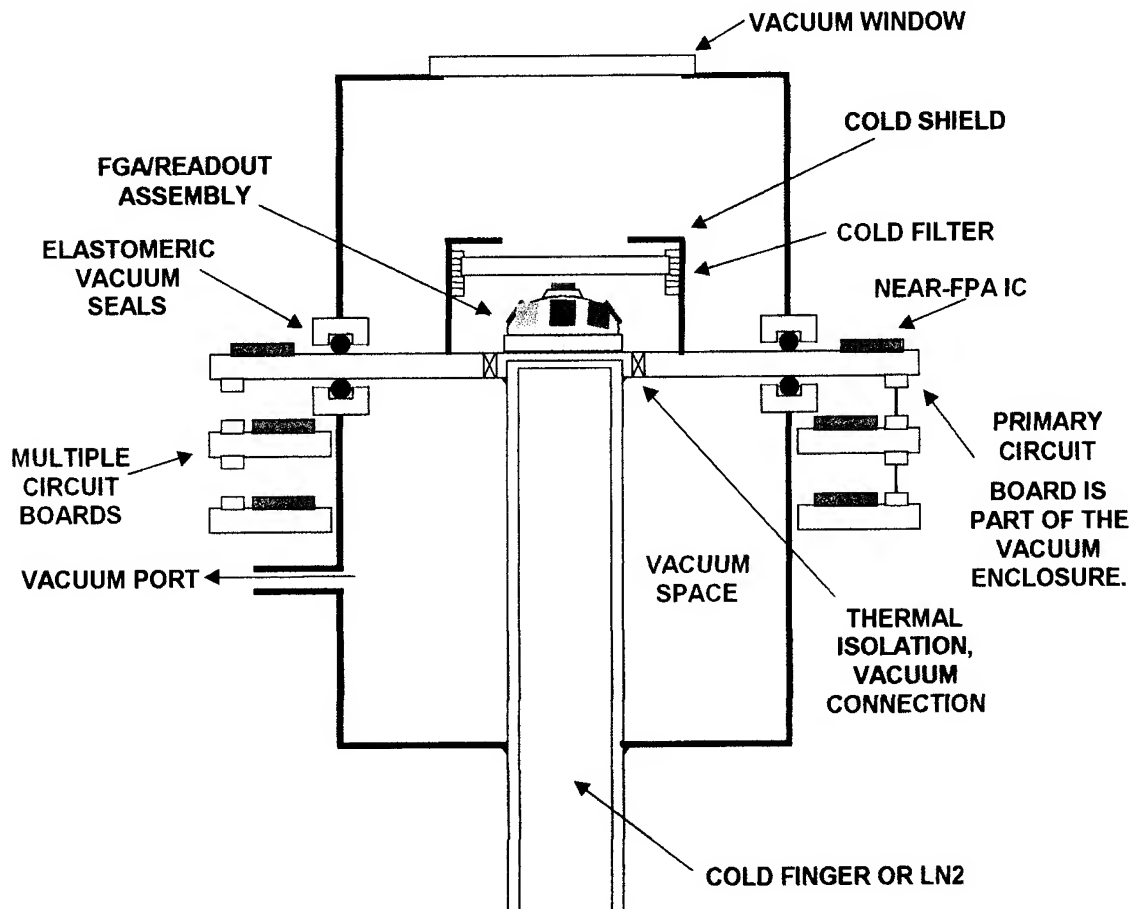


**Figure 3.1-1. A conceptual FGA provides mounting surfaces for flat silicon die on a three-dimensional surface whose shape is determined from the optical system's focal surface.**

In addition, the micro-dewar's design permits the use of liquid nitrogen as the cooling medium, or a self-contained cryo-refrigerator utilizing a cold finger that is inserted behind the cold stage. A complete imaging and processing sensor system will result from the Phase II effort that satisfies the goals of the Guidance Integrated Fuzing mission.

Figure 3.1-2 shows preliminary dewar hardware indicating the relative size of components. This system is small enough to be incorporated as the guidance and fuzing sensor in a missile interceptor, or for performing data collection tasks on Unmanned Air Vehicles (UAVs) and other airborne platforms. The small size and superior performance of this system combined with the extraordinarily wide field of view of the optics produced under Optics 1's effort will create a unique commercial product to be offered during the beginning of the Phase II effort.
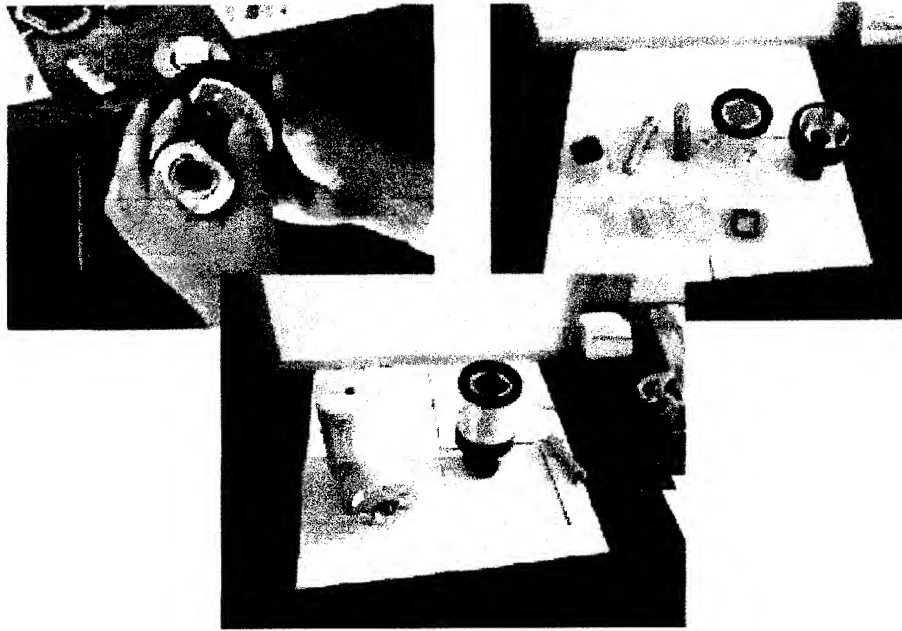
**Figure 3.1-2. Nova's micro-dewar pictured on the right side of the lower inset, with component parts shown in the upper two insets.**

3.2    The Advanced Capability of Biologically-Inspired Analog Processing

Many years of investigation in the field of biologically-inspired vision algorithms has led the staff at Nova Research to propose conventional as well as biologically-inspired processing operations to perform a variety of real-time tasks. After contract award and as the program proceeds, a digital computational throughput equivalent of the chip's algorithm set will be computed; from previous work with NeuroSeek[1], it is expected that this number will be well over **two billion** floating point operations per second.

The massively parallel analog Neuromorphic computations which are performed in CMOS (complementary metal-oxide-semiconductor) are performed for "tens of milliwatts", depending upon the type of computation. This is many hundreds to perhaps a thousand times less than would be required by conventional digital devices (although digital processor technology continues to advance). It is necessary, though, for such analog operations to be effectively performed close to the FPA such that the effects of analog noise sources may be minimized. In the human visual system, major preprocessing functions such as edge detection and preliminary motion processing are performed directly behind the detector cells. Further levels of image processing to determine the essential nature of the image type and preliminary association/characterization operations are performed in the neural pathway (specifically, in the lateral geniculate nucleus) as the signals are reduced to their lowest forms for transmission to the brain. The analog processing to be described in the following example mimics actual human vision as described by Marr[2] as applied to a GIF application. **The following example is given to indicate Nova's general capability for incorporating sophisticated processing functions with real-time video imagery at the integrated circuit level.**

---

[1] Massie, M. A., C. R. Baxter, B. L. Huynh, P. L. McCarley, "NeuroSeek Dual-Color Image Processing Infrared Focal Plane Array", SPIE AeroSense 1998, Focal Plane Array Electronics IV, Orlando, 1998.

[2] Marr, David, Vision, pp. 159-182, W. H. Freeman and Company, New York, 1982.

3.2.1   Insensitivity to Pedestal Variations

The example which follows is used to demonstrate the capability for Neuromorphic techniques to enhance a system's ability to perform guidance and fuzing control functions.   The sequence of input scenes was provided by Mr. Dennis Garbo of the Kinetic Kill Hardware In The Loop (KHILS) scene generation group at Eglin AFB, FL.  After contract award, other target/background scenarios that are of general interest to the government will be requested to be used in a feasibility analysis for the device to be developed.

Nova Research, Inc. has established the conceptual design for an analog co-processing integrated circuit that computes a real-time Difference of Gaussians (DoG) image as well as a "zero-crossing" (ZC) image, in support of an overall sensor-based system that would support GIF functions in the analog signal domain.

Figure 3.2-1 shows how a DoG operation can permit the operation of an infrared sensor in the presence of a time-varying background radiance.  This would essentially eliminate the sensitivity of an infrared sensor system to changes in ambient illumination conditions, a very useful feature for a sensor which may be tasked with operating over a very wide range of conditions.

A 300-frame simulation was performed using a dataset provided by the KHILS group, and four representative frames are given here as an example. The upper four frames show the input sequence from the dataset, in which the entire frame has had an offset signal added to it equal to the maximum pixel value in the frame.  This is representative of a worst-case condition of background fluctuation due to ambient illumination effects.  Notice that the image contrast is greatly affected by such offset changes.  The upper frame sequence is displayed such that each frame has the same display properties; contrast differences are produced by the time-varying background level.

The middle frames of Figure 3.2-1 are the result of passing the upper frames through a DoG filter.  The DoG output does not show the effects of low spatial frequency variations within the scene.  It is a perfect filter for applications in which the entire background is varying at spatial frequencies that are lower than the pixel spatial frequency.  This algorithm can be performed in the near-FPA processing architecture as developed under this program.

The lower frames of Figure 3.2-1 show how a zero-crossing filter may be used to isolate the edges within the scene after a DoG operation, preserving the essential geometries within the scene while eliminating the grey level depth.  This would be useful for aimpoint prediction processing and other operations that do not need the full dynamic range of the scene data.

The beginnings of a conceptual chip floorplan are shown in Figure 3.2-2.  An analog coprocessing chip as shown would have the capability to process entire 256 x 256 scene data at the frame rate.  The chip would be located on a daughterboard of the dewar, and would function so as to perform the DoG function AND the zero-crossing function.  This device would have the capability to produce the middle- and lower-sequences as shown in Figure 3.2-1.
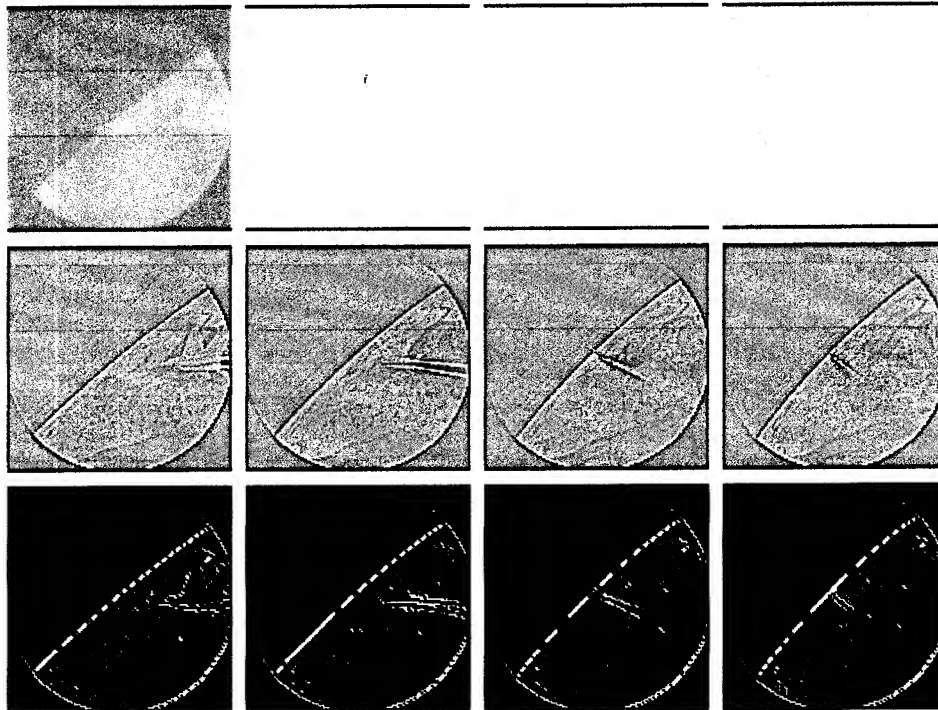
Figure 3.2-1. Upper frames show a simulated sequence of images that have been contaminated by a time-varying background radiance that does not show up in the DoG-filtered imagery as shown in the middle frames. Lower frames show the result of a zero-crossing filter, used to retain edge locations in a binary representation.
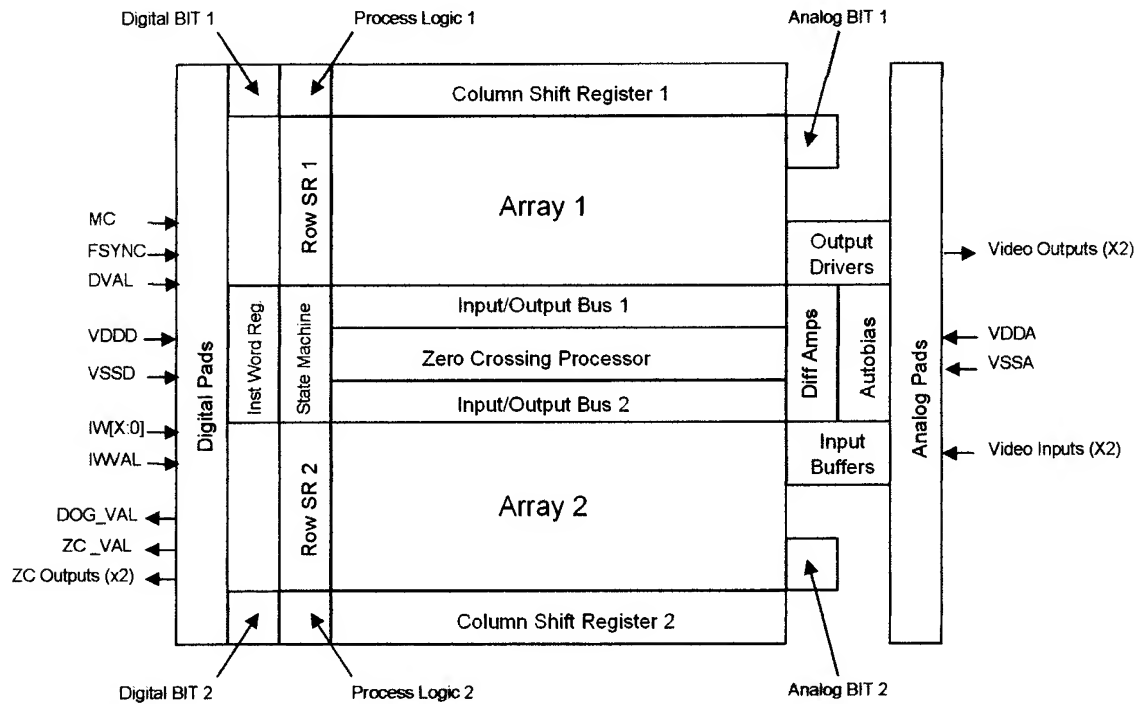


Figure 3.2-2. Conceptual DoG/ZC chip floorplan, sized to process 256 x 256 real-time imagery.

8

3.2.2    Fuzing Control Application

The KHILS-provided simulation data included both port and starboard image sequences for a system that included two $2\pi$ steradian "fisheye" lenses, one on each side of the missile body. DoG and Zero Crossing filters applied to the port and starboard input sequences for a "near miss" condition produce a reduced set of data on which a simple fuzing control algorithm may be applied. Figure 3.2-3 shows selected frames of the result without the effects of aerothermal lens heating included.



**Frame 190**                    **Frame 205**
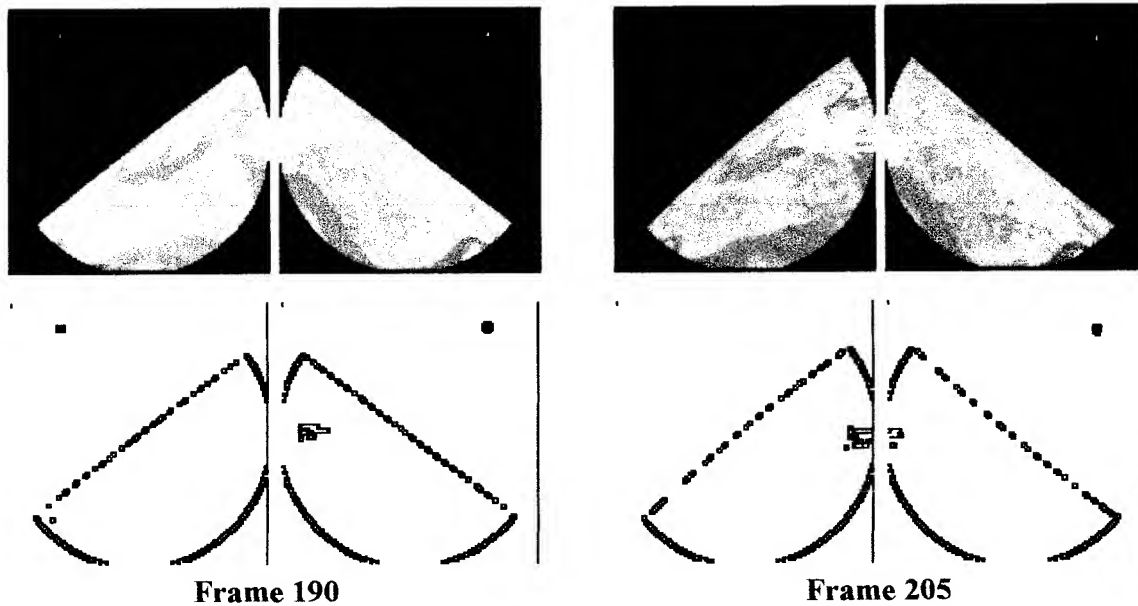
**Figure 3.2-3.  Port and starboard imagery for frames 190 and 205, respectively, for a near-miss intercept condition are shown in the upper frames. Lower frames are the result of near-chip DoG and zero-crossing processing, showing spatially unbalanced and balanced plume location conditions.**

A simple algorithm may now be applied to assess the "spatial balance" condition of the target's plume. From the figure, frame 205 shows a better spatial balance condition, indicating that the target is more nearly centered in front of the interceptor than that shown in the frame 190 condition. This would provide an important input to an overall fuzing control system.

Figure 3.2-4 shows the same sequence as Figure 3.2-3, but now the effects of aerothermal heating have been included, which reduce the image contrast in leading-edge regions of the fisheye lens. Fortunately, the DoG operation (which must be used as a precursor to a zero-crossing detection function) is insensitive to such low spatial frequency grey level variations (as demonstrated previously in Figure 3.2-1), and the zero-crossing result is virtually identical to that of Figure 3.2-3.

Also notice that the actual image regions shown in these figures are circular, by virtue of the field distortion produced by the wide field-of-view (FOV) fisheye lenses. The corners of a rectangular FPA do not convey any image data because the image format is gone in these regions. As a part of the feasibility study and initial design of the FGA, a variety of individual FPA design options will be considered including the use of radially symmetric geometries with radial readout directions. This would enhance the amount of relevant image data, with potentially a better interface to the special wide FOV optics. Designers at Nova are skilled in "Readout and Processing Integrated Circuit" (ROPIC) design, and would be pleased to work together with another contractor, Amherst Technologies (Caesar Bandera) on this aspect of the program.

9

| Frame 190 | Frame 205 |
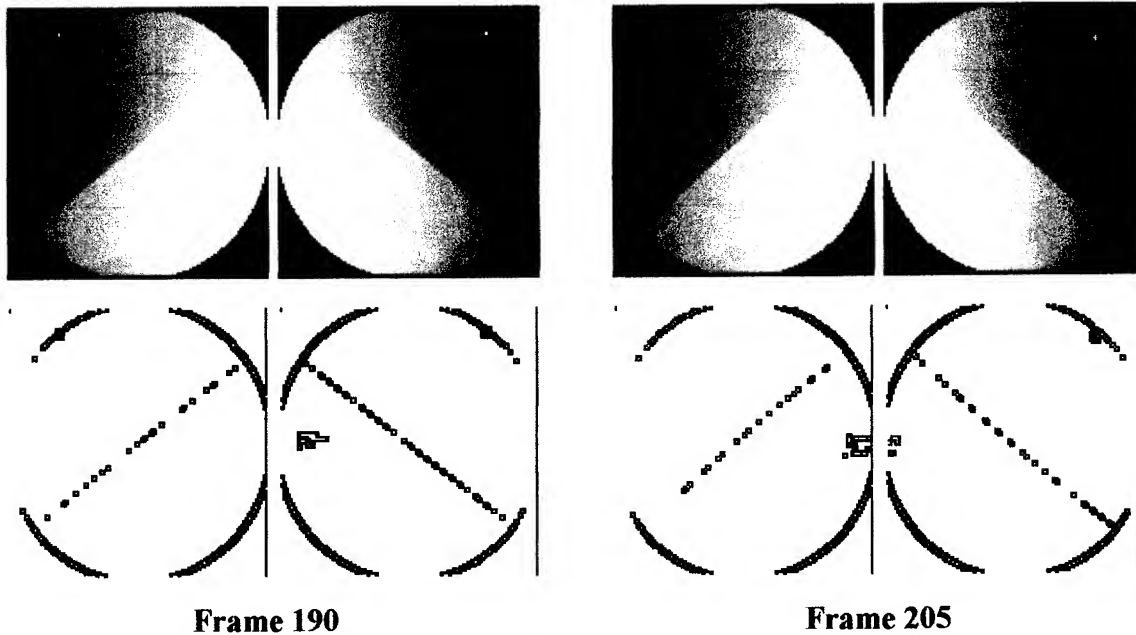
**Figure 3.2-4. Aerothermal heating introduces a thermal gradient in the scene such that the leading edge of the fisheye lens is much hotter than the trailing edge. Near-chip DoG and zero-crossing detection techniques are insensitive to the thermal gradient.**

3.2.3    Guidance Integrated Fuzing

The innovation proposed under this program combines the novel wide-angle optics designed and produced by Optics 1, Inc. with the on- and near-chip processing produced by Nova Research, Inc., into a single detector structure that itself combines the operations of image sensing for guidance and Fuzing control. Combined with existing micro-dewar hardware, a combined system would be fabricated, tested and offered as a commercial product in the Phase II effort.

A first step in the realization of a "non-flat" FGA is proposed in which a small number of flat FPAs will be used on a machined substrate. The surfaces on which each FPA are mounted will be flat, but these imaging devices will be oriented with respect to one another on a focal surface dictated by the focal surface condition of the unique system optics.

A single mission processor will be used to process the resulting image data; imagery required for missile guidance will be produced in parallel with imagery and preprocessed data required for the ordnance fuzing function. Wherever possible on- or near-FPA processing will be used to reduce the volume of image data such that only the most relevant information is used for respective guidance and fuzing functions.

## 4.0    PHASE I TECHNICAL OBJECTIVES

The primary objectives of this Phase I program are:

- Assess the feasibility of producing an FGA substrate designed to conform to the image plane condition of wide FOV optics, and which supports the use of multiple flat FPA devices.
- Define the signal generation requirements needed to operate multiple FPA devices on the FGA structure.

10

- Define the preprocessing operations required for each of the FPA devices so as to provide simultaneous image data for both guidance and fuzing operations.
- Produce preliminary designs for required FPA ROPICs and image preprocessing integrated circuits.
- Define a solid plan to transition the resulting FGA-based system into a commercial application.

The following tasks will be performed in this Phase I program:

1. Collaborate with optical designers at Optics 1, Inc. to define the surface shape for the FGA structure.
2. Assess a variety of techniques that could be used to provide the electrical interconnections required to operate multiple FPA devices as mounted on the FGA surface.
3. Consider mechanical, thermal and electrical properties involved in how the FGA would be integrated into Nova's micro-dewar assembly.
4. Identify the required real-time information necessary for both the guidance and fuzing control operations. This will help define required real-time preprocessing operations required to enhance the system's capability as a GIF sensor.
5. Define the properties of real-time preprocessing integrated circuits or board-level circuit designs to be used to satisfy the data requirements of Task 4.
6. Identify potential commercial applications and a Phase II partner that will be useful in bringing a commercial product utilizing this technology to market.
7. Write a final report that will be used as a basis for the Phase II hardware development effort.

## 5.0    PHASE I WORK PLAN

Seven tasks are included in this nine-month program. The majority of the technical work will be performed in the first six months of the program, and the cost proposal will indicate the total dollar amount associated with the complete program as well as that in the first six months.

### 5.1    Task Descriptions

- **Task 1 - Collaborate with optical designers at Optics 1, Inc.**

    - In the spirit of the SBIR program, continue the collaboration with Optics 1, Inc. that has already been established between these two small companies. Through this collaboration, define the shape of the FGA which must be used to perform the combined guidance and fuzing control functions through the use of specially-designed wide FOV optics with an aerothermal dome structure.
    - Define FPA-related geometries that would be applicable to the image format produced by the system optics. This may include the development of foveated pixel arrangements so as to accommodate image plane distortions produced by the system optics. Such pixel arrangements may take the form of hexagonal pixels, or rectangular unit cells arranged in hexagonal arrangements so as to accommodate a radially-symmetric focal plane array pattern. Related to this will be the conceptual development of readout structures required to be designed for such non-rectangular FPA devices.
    - This task will be performed within the first six months of the program.

11

- **Task 2 – Assess techniques for interface of multiple FPAs on the FGA structure.**

    - Unlike conventional FPA mounting techniques, the FGA structure must have the capability of operating multiple FPA devices in parallel. A wire-bonding or micro-cable technique must be developed so as to provide required stimulation signals to the various FPA devices as well as conduct individual FPA outputs to the primary circuit board of the micro-dewar assembly.
    - Thermal, mechanical and electrical issues will be identified relating to the mounting of numerous FPA devices on a single machined substrate. Optical alignment issues associated with the fixed mounting of numerous FPA devices on the FGA will be considered.
    - Provide a clear low-risk/high confidence path to implementation of the resulting technique in the following Phase II effort.
    - This task will be performed within the first six months of the program.

- **Task 3 – Consider electrical, mechanical and thermal interfaces of the FGA in the micro-dewar.**

    - Vacuum feedthrus are eliminated through the use of Nova's micro-dewar, so this should offer a significant advantage over conventional dewar electrical interconnection methods. Combined with Task 2 above, this effort will define other aspects of the electrical design of the system required to operate multiple FPA devices as mounted on the FGA.
    - The mass of the FGA substrate will affect the efficiency of the cryogenic system required to cool the infrared detectors. Design issues regarding the mechanical aspects of the FGA (i.e., solid or reduced-mass designs) will be considered based upon the cooldown times expected to be required for interceptor missions.
    - This task will be performed within the first six months of the program.

- **Task 4 – Identify required guidance and fuzing control data to be produced by the system.**

    - A number of preprocessing operations may be applied to the real-time imaging data produced by the various FPA devices located on the FGA structure. These operations would be used to prefilter the data such that preliminary guidance control signals could be produced directly at the sensor.
    - Based upon fuzing control concepts included in this proposal as well as others to be defined as a result of sponsor meetings, algorithms will be described to aid in the rapid assessment of target location for autonomous fuzing control.
    - This task will be performed within the first six months of the program.

- **Task 5 - Define the properties of real-time preprocessing integrated or board-level circuits.**

    - As a result of the required data and algorithms defined in Task 4, a variety of real-time image and data processing operations will be defined.
    - These operations will be partitioned with respect to their individual hardware implementations. Some of these operations should be performed in a massively parallel implementation on "near-FGA" analog coprocessing integrated circuits, others at the board-level on a micro-dewar daughterboard.
    - Operations to be performed may include, but not be limited to the following: Clutter rejection, edge enhancement, edge extraction, spatial nonuniformity correction, target location processing, evaluation of target-to-interceptor position and range, two-dimensional interceptor pointing angle errors, target position prediction processing and aircraft control signals.

- A portion of this task will be performed within the first six months of the program.

- **Task 6 - Identify potential commercial applications and a Phase II partner.**

    - Numerous commercial applications will result from this technology development by virtue of the operational flexibility and sophisticated real-time image processing capabilities of the miniature infrared sensor system. These may include autonomous fire safety sensors, collision avoidance systems and numerous military applications. This task will include an investigation of the market potential of such a system.
    - A commercial partner will be identified to assist Nova Research, Inc. in the marketing and distribution of the resulting commercial product. In the past, the SE-IR Corporation, a well-known manufacturer of infrared systems electronics, has offered support to Nova's commercialization and marketing efforts. This relationship will continue to be developed through this Phase I effort.
    - This task will be performed in the last three months of the program.

- **Task 7 - Write a Final Report**

    - A final report will be written, documenting all designs, concepts, simulations, applications and potential commercial areas that may use this technology. It will provide the technical basis for the complete design and fabrication effort to be performed in a Phase II program.
    - This task will be performed in the last three months of the program.

## 5.2    Schedule

A nine month program is proposed that will analyze feasibility and produce preliminary designs for a "Focal Geometric Array" (FGA) structure to be incorporated into a micro-dewar in a following Phase II effort. Using the FGA structure and specially-designed wide FOV optics, the resulting imaging system will have the capability to combine the guidance and fuzing functions of missile interceptors now performed by separate subsystems.

As shown, the major technical effort of the program will be performed within the first six months of the program. The remaining three months will be used for documentation and commercialization aspects of the program. Nova sees a tremendous commercial potential for such a miniature infrared camera system that has the capability to perform sophisticated image processing directly at the camera head. For this reason, significant company effort will be invested in the commercialization task.

| | TASK DESCRIPTION | GFY99 | | | | | | GFY2K | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | A | M | J | J | A | S | O | N | D |
| | Kickoff Meeting | △ | | | | | | | | |
| 1 | Collaborate with optical designers at Optics 1, Inc. | | | | | | | | | |
| 2 | Assess techniques for interfacing multiple FPAs on the FGA structure. | | | | | | | | | |
| 3 | Electrical, mechanical and thermal interfaces of the FGA in the micro-dewar. | | | | | | | | | |
| 4 | Identify required guidance and fusing control data to be produced by the system. | | | | | | | | | |
| 5 | Define the properties of real-time preprocessing integrated or board-level circuits. | | | | | | | | | |
| 6 | Identify potential commercial applications and a Phase II partner. | | | | | | | | | |
| 7 | Document all designs and write a Final Report. | | | | | | | | | |

**Figure 5.1   The Phase I schedule is based on a nine month program with the majority of the technical effort completed within the first six months.**

## 6.0    RELATED WORK

6.1    The Smart Neuromorphic Infrared Focal Plane Array (SNIF)

Mr. Massie led a team of engineers at Amber Enginering (1991-1993) in the development of the first infrared FPA which incorporated an integral network of switched capacitors required to perform a real-time Difference of Gaussians operation in the analog domain. Patterned after pioneering work performed at Cal Tech on the "Silicon Retina", the SNIF demonstrated the feasibility of using high density circuitry to model some of the computational structures used by biological imaging sensors (i.e., retinas). An operational sensor was designed, fabricated, and was demonstrated to operate in the 3 to 5 micron region of the infrared spectrum[3]. This was the beginning of Mr. Massie's mutual relationship with the Air Force Research Laboratory, and led to the development of the NeuroSeek device.

6.2    On- and Near Focal Plane Array Image Processing

Mr. Massie has led the development of new technologies in the area of on-chip and near-chip image processing for infrared applications. At Pacific Advanced Technology (1993-1998), he led programs which developed operating analog frame buffers on an infrared focal plane array (NeuroSeek[4]), and at Nova Research he has been developing initial designs for near-FPA analog coprocessing integrated circuits and their associated electronic systems for use in both Air Force and Navy applications (Air Force contract # F08630-98-C-0078 and Navy contract # N00014-98-M-0175, respectively).

The document list given in Section 9.0 indicates the variety of topics and applications related to real-time massively parallel analog processing for infrared imaging applications.

6.3    Development of the First 512 x 512 Infrared FPA

Designers at Nova have many years of experience developing new technology involving infrared science. This section is included to demonstrate the involvement of our engineering staff in the development of the world's largest infrared focal plane array of its time.

High speed frames of infrared camera imagery were required to satisfy requirements of missile interceptor systems that the BMDO were designing in the first part of the 1990's. At the same time, Amber Engineering was interested in finding a source of funding to produce the largest-ever InSb FPA; at the time, a 128 x 128 InSb FPA was the largest product that the company offered for commercial sale. Through association with people within BMDO, a program was initiated called the "Advanced Large Area Infrared Transducer", ALIRT. Two of the important results of this program were to produce the first 256 x 256 InSb FPA, followed by the world's first 512 x 512 pixel InSb FPA. Mr. Massie acted as the Systems Engineer on this program and was involved in specifying and simulating the ROI aspects of how the device would operate. This program turned the BMDO-specified requirements into the world's first operating high-speed dynamically-addressable "Region of Interest" ROI (windowing) readout.

Numerous technical challenges were addressed and solutions were found and applied to the resulting design. The frame rate for the full-frame device was targeted to be 60 Hz ,and with 262,144 pixels per

---

[3] Massie, M. A., J. P. Curzan and P.L. McCarley, "Neuromorphic Infrared Focal Plane Performs Pixel-Based Sensor Fusion", IRIS Specialty Group on Passive Sensors, Johns Hopkins University, 1993.

[4] Massie, M. A., C. R. Baxter, B. L. Huynh, P. L. McCarley, "NeuroSeek Dual-Color Image Processing Infrared Focal Plane Array", SPIE AeroSense 1998, Focal Plane Array Electronics IV, Orlando, 1998.

frame, this translated to a combined pixel rate of approximately 20 megapixels/second. Four output channels were designed into the device such that each channel would be digitized off-FPA at a rate of 5 MHz. We began to realize that a tremendous quantity of pixel values could be produced from such a device, and the majority of pixels to be multiplexed off the FPA had no useful data to be used for missile seeking, identification, etc.

Most of the frame period in the full-frame mode is wasted on multiplexing out useless data if the target to be tracked is a point-like object. It was decided through discussions with our sponsor at the time that some form of "Region of Interest" output multiplexing would be required to preserve high effective frame rates while at the same time retaining all of the salient image data. Two possibilities were identified: (a) obtain high effective frame rates while preserving high spatial resolution by defining a contiguous region of pixels to pass out from the device, or (b) obtain high effective frame rates while preserving Total Field of View (TFOV) (i.e., by sacrificing spatial resolution) by "summing" the signal responses of contiguous pixels, forming "superpixels". Either technique would produce high effective frame rates.

It was decided that high spatial resolution (i.e., small Instantaneous Fields of View, IFOV) was more important than Total Field of View for the case in which a seeker would need fast updates to produce accurate maneuvering commands. For this reason, the command word to be written to the FPA would include 20 bits of information, five bits each for the X and Y positions of the upper-left corner of the ROI, and five bits each for the height and width of the ROI to be used. Since there are 512 pixels in each dimension, and since 5 bits corresponds to 32 divisions in the 512-pixel range, the "granularity" of ROI control for this device was 512/32 = 16 pixels. This means that the size and location of the commanded ROI may be controlled to a 16-pixel quantization, in the range of from 16 pixels (in location or size) to 512 pixels (fixed position, and filling the entire field of pixels in the FPA).

Figure 6.3-1 schematically represents this device, and indicates that a number of bias voltages and clock-like signals required to operate it in its various modes of operation.
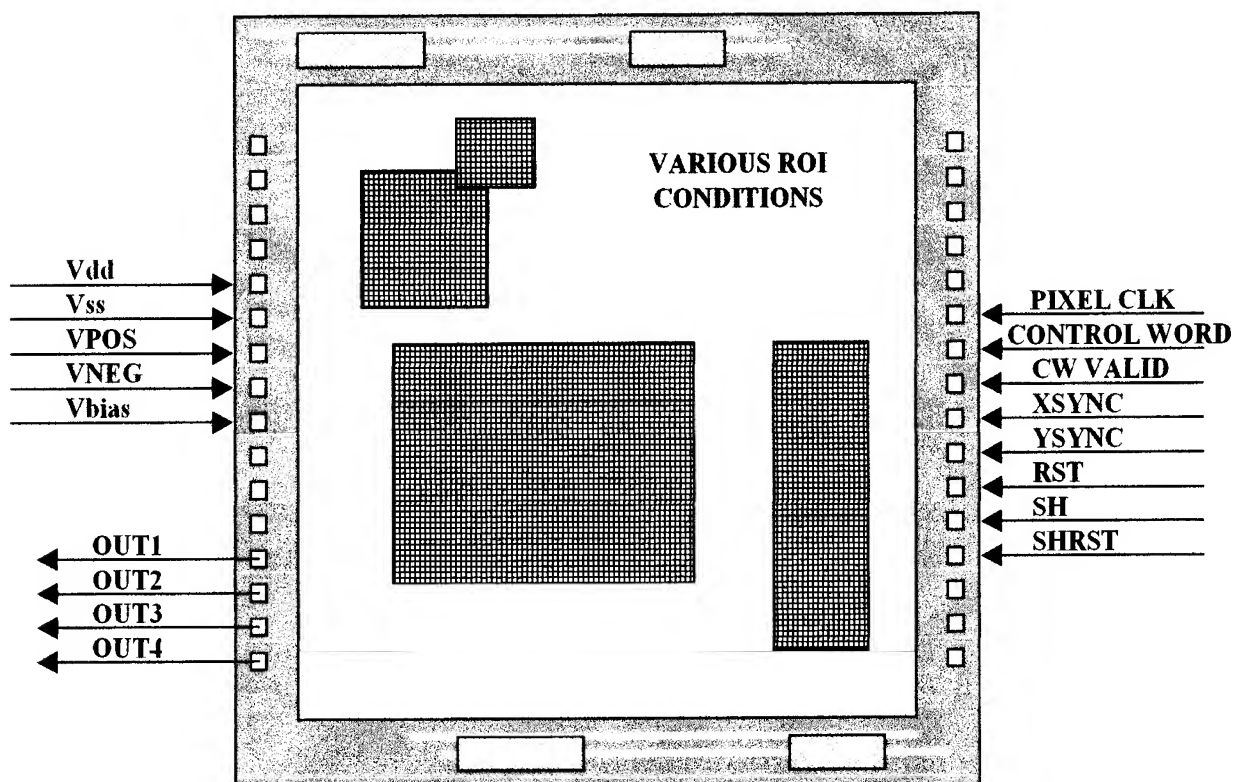
**Figure 6.3-1 Representation of the AE187 ROIC and serial control word methodology**

Other significant technical challenges were faced and overcome in the development of this large-area device, having to do with the thermal mismatch which existed between the InSb detector array and the underlying silicon readout structure. The large dimensions of this readout can produce enough linear contraction during cooldown from room- to liquid nitrogen temperature to actually crack the thin detector array. The ALIRT program developed a proprietary technique to minimize this effect, producing reliable 512 x 512 FPAs free of this potential defect mechanism. Most area-type infrared FPAs produced today make use of a "hybrid" technique which electrically and mechanically connects a very thin detector array to an underlying silicon readout structure through the use of indium-bump technology.

Since the advent of the AE187, other manufacturers have now incorporated real-time ROI control to their readout designs. Such FPAs may in fact be used on the Focal Geometric Array proposed for development under this program.

6.4    Company and Principal Investigator Background

Mr. Massie is the President and a principal partner of Nova Research, Inc. Nova's mission is to develop advanced miniature sensors for use in the military and commercial domains, designed to achieve humanitarian goals. Throughout his career, Mr. Massie has been the responsible principal investigator for four Phase I SBIRs, two Phase II SBIRs, one Phase III SBIR, a sole-source contract with ONR, space-based infrared cameras, associated electronics, and a variety of other sensor system development programs.

Nova Research, Inc. was incorporated in the second quarter of 1998, and the staff at Nova has many years of experience in the design and development of state-of-the-art electro-optic sensor systems. The tremendous experience base of Nova's staff and the success of many previous sensor and sensor system development programs led by Nova's team forms a basis for the development of new systems. A sampling of past programs from the combined technical expertise of Nova's staff is given below:

**Satellite Camera and Signal Processing Electronics** – Nova Research, Inc. is currently designing and developing a spacecraft payload electronics package for the Navy's "Naval Earthmap Observer", NEMO, to be used in Earth resources monitoring applications.

**Smart Neuromorphic Infrared Focal Plane Array (SNIF)** - The first-ever infrared focal plane device designed to operate like that of a human retina was developed, characterized and demonstrated by Mr. Massie and his design group when they were at Amber Engineering.

**Infrared Camera Electronics-** At Pacific Advanced Technology, Mr. Massie's team developed electronics to drive large focal plane arrays (up to 1024 X 1024 pixels) including all camera support electronics. This system provided high frequency scanning rates, region of interest zoom capability, on-the-fly nonuniformity correction, etc. This system is now available in the commercial market from Pacific Advanced Technology.

**On-Chip Infrared Spectrometer Design (Phase I SBIR, ARPA)** - The algorithms required to realize an infrared spectrometer function directly on the imaging sensor of an advanced focal plane array were developed and tested under this Phase I SBIR program by Mr. Massie while at Pacific Advanced Technology.

16

**Neuromorphic 256 x 256 Pixel Two-Color Infrared Seeker for Smart Munitions and Sensor Fusion Applications (Phase II SBIR, AF)–** Under the technical direction of Mr. Massie while he was at Pacific Advanced Technology, this program developed a VLSI circuit with on-chip frame buffers incorporated on the focal plane such that higher-level on-chip processing functions for motion detection of low observable targets could be performed in real time.

**Clementine Space-Based Infrared Camera Systems (NRL, LLNL)** – At Amber, Mr. Massie was the lead project engineer and the developer of the Clementine Space-based infrared cameras which were placed into lunar orbit and successfully mapped the entire surface of the moon.

**MSTI III Infrared Sensor Engines (Phillips Lab, SAIC)** – Also while at Amber, Mr. Massie was the lead project engineer for the infrared sensor engine assemblies used on the Miniature Seeker Technology Integration (MSTI III) spacecraft mission that was successfully flown in low earth orbit in 1996 and 1997. This mission was responsible for collecting earth phenomenology data for national defense applications.

## 7.0 RELATIONSHIP WITH FUTURE RESEARCH OR R&D

Nova Research, Inc. is interested in helping to develop advanced imaging technologies of the future. These areas include the application of a variety of powerful image and signal processing operations either directly on the FPA, or very near to it such that computationally powerful operations may be performed for only milliwatts of power. A concurrent STTR program at Nova is developing "near-FPA" coprocessing chip designs for this use. This program fits perfectly with the overall concept of developing smaller, more computationally powerful, higher performance and more cost-effective imaging and processing solutions for military and commercial applications than has ever been available in the past.

Commercial applications demand high performance at low cost, and the innovation proposed in this program represents a significant improvement in the performance of autonomous infrared seeker technology. The combination of guidance and fuzing control functions into a single sensor system, developed through the synergistic relationship of two small companies represents the true spirit of the SBIR program. Nova Research would like to be involved in the development and growth of this exciting aspect of the infrared industry, and is willing to commit its resources to ensure a successful program.

## 8.0 POTENTIAL POST APPLICATIONS

Important commercial and military applications of such a device could include:

- Man-portable, airborne or spaceborne sensor used for target detection in applications relating to the national defense.
- Image processing infrared applications that require the identification or characterization of real time imagery.
- Sensor arrays which themselves produce intelligent control outputs for machine or vehicle control, detection alarms, haptic (i.e., touch-sensory) sensor inputs, etc.
- Search and rescue imagers that are not affected by night operations, smoke or fog. A low-cost infrared version of this technology could be used to save lives by permitting firefighters to find incapacitated victims overcome by smoke inhalation.
- Aircraft collision avoidance applications.
- Wide field-of-view applications eliminating the need for expensive gimbaled system optics.